

Li-Be-B isotopic compositions of CAIs in the Yamato 81020 CO3.05 chondrite: Implication for the origin of ^{10}Be in the early solar system.

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Introduction: Beryllium-10, which decays to ^{10}B with a half-life of 1.4 Myr [1], is considered as a key indicator of irradiation processes in the early solar system (ESS). However, recent numerical studies have shown that ^{10}Be can be produced by neutrino reactions with core-collapse supernovae [2,3], which rendered reconsideration of the origin of ^{10}Be in the ESS. The stable isotopes of Li, Be, and B are also made by irradiation and neutrino processes [e.g., 2-4]. Thus, the quantitative understanding of initial ^{10}Be abundances and stable Li-Be-B isotopic compositions would provide important constraints on the origin of ^{10}Be in the ESS. Previous studies have provided hints for in-situ irradiation signatures of $^7\text{Li}/^6\text{Li}$, initial $^{10}\text{B}/^{11}\text{B}$ and initial $^{10}\text{Be}/^9\text{Be}$ ratios in coarse-grained Ca-Al-rich Inclusions (CAIs) in CV3 chondrites [e.g., 4-9]. Up to now, limited data set have been reported for CAIs in other types of chondrites, most likely due to the small grain sizes. To further understand the origin and distribution of ^{10}Be , we have conducted Li-Be-B measurements on CAIs in the Yamato 81020 (hereafter Y81020) CO3.05 chondrite using high spatial resolution SIMS.

Experimental: Two melilite-rich CAIs, Y20-1X1 and Y20-9-1, were selected from the Y81020 meteorite. Petrographic observations and major element concentrations of these CAIs were obtained with JXA-8530F FE-EPMA at Department of Earth and Planetary Science, the University of Tokyo. Lithium and Be-B isotopic measurements were performed with the NanoSIMS 50 installed at Atmosphere and Ocean Research Institute, the University of Tokyo. The NanoSIMS measurements were performed in a multi-collection mode. An $^{16}\text{O}^+$ primary ion beam, $\sim 5\text{nA}$ intensity and $\sim 7\text{ }\mu\text{m}$ in diameter, was rastered over $10 \times 10\text{ }\mu\text{m}^2$ sized areas. For the Li isotopes, secondary ions of $^6\text{Li}^+$, $^7\text{Li}^+$, and $^{30}\text{Si}^+$ were detected simultaneously with three electron multipliers. For the Be-B measurements, secondary ions of $^9\text{Be}^+$, $^{10}\text{B}^+$, $^{11}\text{B}^+$, and $^{30}\text{Si}^+$ were detected simultaneously with four electron multipliers. The $^9\text{Be}/^{11}\text{B}$ relative sensitivity factor was determined from measurements of synthetic melilitic glasses [10].

Results and Discussion: Y20-1X1 and Y20-9-1 CAIs yield isochrons with initial $^{10}\text{Be}/^9\text{Be}$ ratios of $(3.02 \pm 0.37) \times 10^{-3}$ and $(2.16 \pm 0.97) \times 10^{-3}$, respectively. The initial $^{10}\text{Be}/^9\text{Be}$ ratios of CO CAIs are slightly higher than those of CV canonical CAIs (e.g., 0.88×10^{-3} [4]). If the variation in the initial $^{10}\text{Be}/^9\text{Be}$ ratios between CO and CV CAIs were produced by in-situ cosmic ray irradiation, initial $^{10}\text{B}/^{11}\text{B}$ and $^7\text{Li}/^6\text{Li}$ ratios would be affected by spallation products. However, Y20-1X1 and Y20-9-1 show chondritic $^{10}\text{B}/^{11}\text{B}$ ratios within uncertainties (0.251 ± 0.004 and 0.269 ± 0.093 , respectively). In addition, these CAIs also show chondritic $^7\text{Li}/^6\text{Li}$ isotopic ratios (12.18 ± 0.17 and 12.04 ± 0.28 , respectively). These results are broadly consistent with our previous work of CAIs in CH and CH/CB primitive chondrites [11]. In order to understand the observed relationship with the initial $^{10}\text{Be}/^9\text{Be}$, $^{10}\text{B}/^{11}\text{B}$, and $^7\text{Li}/^6\text{Li}$ ratios, we estimated spallation effects on $^{10}\text{B}/^{11}\text{B}$ and $^7\text{Li}/^6\text{Li}$ in CAI-like compositions using the observed initial $^{10}\text{Be}/^9\text{Be}$ ratios and spallation production ratios [12]. Considering concentrations of Li, Be, and B in Y20-1X1 and Y20-9-1, this simple calculation suggests that the observed $^{10}\text{B}/^{11}\text{B}$ and $^7\text{Li}/^6\text{Li}$ ratios are inconsistent with in-situ irradiation of CAI-like materials. If CAI-like materials (e.g., Li $\sim 600\text{ppb}$, Be $\sim 700\text{ppb}$, and B $\sim 10\text{ppb}$) were irradiated and ^{10}Be was produced at a level of $\sim 3.02 \times 10^{-3}$ in the initial $^{10}\text{Be}/^9\text{Be}$ ratio, the expected $^7\text{Li}/^6\text{Li}$ and initial $^{10}\text{B}/^{11}\text{B}$ ratios are ~ 1.8 and ~ 0.43 , respectively. The inconsistency between observed isotopic ratios and calculated ratios could be attributed to: (a) ^{10}Be was not produced by solar cosmic ray irradiation, but by stellar processes [3], (b) partial loss of spallogenic B and Li and isotopic exchange with a chondritic gas, and (c) condensation from an irradiated chondritic gas. (a) is unlikely because the stellar model proposed by [3] cannot explain such high $^{10}\text{Be}/^9\text{Be}$ ratios observed in this study. (b) is a possible scenario for the Y20-1X1 CAI because petrographic observations suggest that Y20-1X1 was probably once molten. (c) is a simple interpretation. If this is the case, the initial $^{10}\text{B}/^{11}\text{B}$ and $^7\text{Li}/^6\text{Li}$ ratios were less effected by solar cosmic ray irradiation. More data from primitive CAIs that have not been thermally processed (e.g., Fluffy Type A CAIs) will be needed to shed light on the origin of ^{10}Be in the ESS.

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